Perspectives on Operations Research (OR++)

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What is OR?

It’s a Fan!

It’s a Wall!

It’s a Rope!

It’s a Spear!

It’s a Snake!

It’s a Tree!
What is OR?

Operations Research is the discipline that applies various analytical methods to help make decisions, solve real-world problems.

- Above is quite a common description given by students and professionals in OR Community.

Picture that comes to mind:

Real world problems ➔ Solutions via OR methods
OR and its methods

OR primarily focusses on its methods & techniques
- Linear Optimization, Non-linear Optimization, Simulation, Queueing Theory, Meta-heuristics, etc.
- With applications in planning, scheduling, inventory control, etc.

That seems to be our preparation to do

Real world problems

Solutions via OR methods

Hold on to this picture.
- Allow me to share a few cases/ experiences and we will come back to this.
Experience of University Timetabling at IITB

Basically the problem is to figure out the venue and times at which all the different courses are offered.

Why is this a problem? What makes it difficult?

◦ Each semester at IITB, 750+ courses are offered by 500+ faculty to 8000+ students, with each student taking a basket of 2-8 courses (including labs). There are ~80 classrooms available where we hold the lectures.

This is a resource scheduling type problem. `Resources' are: Room, Time Slots, Students, Instructors

◦ We need to schedule the courses on all four resources simultaneously without conflict.
◦ There is no real objective! This is a constraint satisfaction problem.
Building the timetable

Step 1. Design a model (Integer Programming model)
- Identify model parameters and decision variables.
- Express the constraints unambiguously, mathematically.

Step 2. Collect data
- Set of courses, with associated instructors
- Set of room, with capacities.
- Expected course strength.
- Time slot pattern in which to schedule courses.
- Curriculum information of students/degree.
- ... other info.

Step 3. Solve the model
- Using an appropriate method to generate the timetable.
Model Overview

Hard constraints
◦ Every event (course/lab) to be assigned room.
◦ Student to attend at most one event in a time slot.
◦ Only one event is held in a room in a time slot.
◦ Instructor to instruct only one course in a time slot.
◦ Room is sufficient seating and required features.
◦ Student to be able to take a combination of courses as required (core courses) and as desired (electives).

Some Soft Constraints are there too..

This looks like a typical OR work: problem solved?
Problem Solved?  No, due to following reasons

Only 97% of requirements captured.
◦ Half semester courses, 8 credit courses, multi-division courses & labs, tutorials, backloggers, multi-room courses & labs, etc

Flexible and inflexible preferences
◦ Class room in or near own dept., slot & timing choices, student movement

Input, System and Output
◦ Inputs are incomplete, inconsistent, keeps changing; System not easy to use; and output is not easily readable; and Resistance to new way of doing things

Learning: Effort should go beyond apply techniques
What did we do?

Only 97% of requirements captured.
- Remaining 3% needed to make problem complete!

Flexible and inflexible preferences

Input, System and Output

Modeled by (i) updating input set; (ii) creatively capturing inputs (iii) additional/ updated constraints.

An easy-to-use UI to collate inputs, and display outputs.

Learning: Building of a decision support system is not sufficient. A complete action plan required for (i) Stakeholders’ buy-in, (ii) Training, (iii) Active use.
And they did timetabling Happily Every After.

Well, not really...

People love to take decisions: have a say in what/how/when they do.

- Options to modify solutions was needed (sometimes for the better, sometimes for the worse). → post-optimality analysis.

Sustained use of solutions need systemic upgrades and change in way of working.

Learning: An OR person’s work is incomplete until the problem is solved in practice.
Continuous Improvement is needed.

- Efforts in initial years were to get appropriate inputs and in using this solution approach (i.e.) optimization.
- Actual timetable realized in practice and the solutions proposed was then studied carefully.
- An improved approach by partitioning the problem and decentralized decision making adopted: eliminates IP model!

Learning: Focus should be on addressing the problem effectively, and not on technique use.
Experience with Industry

An indicative & diverse list:

◦ Optimization based decision support tool for Alumina Distribution Planning and Scheduling
◦ Developing Optimization Algorithms for manufacturing assembly line simulation models
◦ Lost Sales Prediction Model

Learnings:

◦ Technique/ approach was pre-decided!
◦ Focus on solution rather than understanding, except in one case → Worrisome.
◦ Did these actually help them? → Not sure!
Experience with Socio-Economic Systems

In the experiences shared, the problem itself is quite well defined, with an ‘obvious’ link to techniques.

That need not be the case for socio-economic systems

Experience: *Solar Urja through Localization for Sustainability* (SoULS) initiative of IITB.
About SoULS

Objective: To promote socio-economic development through access to clean, affordable, reliable, sustainable and modern energy access in rural communities.

Sustainable energy access ↔ Off-grid solar solutions.

Localisation, Affordability and Saturation
- Scale and Speed with Skill-development.
SoULS activities and projects

**Provide Solar Study Lamp** for rural school students at a discounted price (Rs. 100/lamp).
- **Locals** assemble & distribute the lamps
- **Locals** provide Repair & Maintenance services during warranty period

**Enterprise Development** of local R&M centers into Solar shops/entrepreneurs.
- Formation of aggregator company for demand and supply aggregation.
- Creation of *Solar Ecosystem for Local by Local* (SELL)

**Manufacturing** of solar PV panels by locally owned manufacturing; **Assembly** of other solar systems
- Further expansion & nurturing of SELL

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70 Lakhs Solar Study Lamp Scheme
5 Lakhs Solar Study Lamp Project

Dungarpur, etc*
Outcome, Activity, Institutions

- **Consumer Energy Access**
  - Solar Urja Lamps at all Households (Basic Needs)
  - Higher Order Energy Needs

- **Local Capacity Building**
  - Basic Technical Capacity
  - Adv. Technical/Mgmt Capacity
  - Entrepreneur Capacity

- **Local Institution**
  - Manufacturing
  - Aggregator Company
  - Retail Shops
  - Service Centers
  - Assembly Centers
Range of ‘problems’

Products design
Project planning & management
Selecting intervention areas
Supply contracts
Network design, Local centers location & setup
Assembly & Distribution
After-sales network
Manage Operations
  ◦ Forward & reverse flow
Staffing and HR
Quality assurance & quality control
Training Content design
Trainings
Documentation
MIS/ Data management
Beneficiary impact studies
Finance and Accounts
Facility Layout
Workflow and Process flow
Etc.

How many of these fall under the ambit of OR Community?
Let’s consider *Durga Energy*

Durga Energy is a solar panel manufacturing facility (MSME), owned and operated by tribal women at Dungarpur.

IITB is to setup, and handhold operations of facility for 2 years.

- Set up involves: Site selection, facility layout, manpower hiring and training, machines procurement and installation, registrations, business planning, etc.

- Post-Commissioning Operations: Production, inventory upkeep, sales and marketing, finance and accounts, planning, HR management, purchase, vendor relations, etc.

How many of these fall under the ambit of OR Community?
Broad learnings from SoULS

People want to ‘solve’ the problem, one way or the other. Decisions needed to be done on-time.
  ◦ Rigorous techniques, though desired, need not be always used.

Scoping of the problem is not straightforward.
  ◦ Structured & focused efforts are required for the same.
  ◦ As a result, OR professionals (& students) find it difficult to contribute

Tendency to look at the problem from the lens of ‘selective’ techniques.

System (world) is going to operate with good, mediocre or bad decisions. It’s not going to wait.
Now, let’s summarize

The following view is insufficient to do full justice to OR as a discipline

Also, important part of OR:
- Problem structuring & modeling;
- Action plan & implementation framework

We should not define OR by its techniques such as LP, Queueing theory, simulation etc.
Reasons not to define OR by its techniques

Focus shifts away from problem and toward technique or technique-specific models
- Lack of importance to get realizable solutions.

Models used to explain techniques rather than problems
- We rarely speak of models as true or false.
- Confirming models empirically must also be part of OR. Models disconfirmed in practice must be rejected.
Reasons not to define OR by its techniques (2)

**Understanding from OR is not emphasized**

- Clients/ Manager treat OR implementations as a ‘black box’;
- No significant attempt to understand and learn from models.
- Moral responsibility of OR "to inform the manager in what respect our 'solutions' have failed to tame his wicked problems”
  – C. West Churchman (Systems Scientist, UCB)

**Hard OR has become an academic discipline rather than a practical profession**

- Hard OR : refers to classical techniques like LP, IP, queueing theory, Regression models, etc.
Reasons not to define OR by its techniques (3)

Resistance to new techniques/ algorithms
- Control theory, fuzzy logic, meta-heuristics, DEA, stochastic methods, system dynamics etc.

OR confused with mathematics and applied mathematics
- OR uses mathematics. (Mathematics operate at higher level of abstraction)
- OR does not simply apply mathematics theory.
- OR has its own theory formation (e.g. scheduling, planning, etc, and NOT directed graph, polyhedra)
Reasons not to define OR by its techniques (4)

Explicit boxing of Applications as being quite distinct from Techniques.
◦ Makes OR professional into “people with hammers”
◦ Worse.. Others tend to perceive us like that!

No one is clear what OR is about
◦ It is not only about ‘Optimization’
KEY reason not to define OR by its techniques

Field is energized by a mystery not the techniques used to probe it.

This is a fundamental reason not to define OR by its techniques. (Hooker 2007)
So, what is OR?

There are quite a few descriptions about what Operations Research (OR) is/ does

Let’s see a few of them...
A few descriptions of OR..

“Operational Research is the attack of modern science on complex problems arising in the direction & management of large systems of men, machines, materials and money in industry, business, government and defense.” - OR Society Quarterly 1962.

“In a nutshell, operations research (O.R.) is the discipline of applying advanced analytical methods to help make better decisions.” - OR: The Science for Better

Some tongue-in-cheek definitions too:
- “Operations Research is the art of giving bad answers to problem which otherwise have worse answers” - T.L.Saaty, Univ of Pittsburg (Invented AHP)
- “I’m an Operations Analyst. I solve problems you don’t know you have, in ways you can’t understand” - Unknown
A few descriptions of OR.. (contd)

Well, do they really capture what Operations Research discipline does?

Let’s go to basics.
Study matter of disciplines

What does physics study?
- The universe and how it works! Studies matter and energy

What does biology study?
- Studies living things

What does social science study?
- Study of human society and social relationships

What does OR study?
- Needs to be defined by the phenomenon it studies (and not techniques)
What does OR study?

OR studies complex human activities and formal structures therein

- Complex human activities: Transport, agriculture, manufacturing, security, health care, waste-disposal, financial services, information, etc.
- Formal structure of human activities: Timetabling, queueing, planning, scheduling, logistics, etc. (Decision-making/ human decisions)
- Involves use of structured, rigorous methods: mathematical and non-mathematical

OR must provide understanding as well as tools.

(Hooker 2007)
Implications: OR gets de-mystified

OR-ers should be unified in telling what OR studies
  ◦ Students should not wait to complete program to figure out what OR is.

Helps attract new and young talent into OR
  ◦ OR has been restricted/ seen as a PG-level specialized activity
    ◦ Perhaps due to its preoccupation with techniques.
  ◦ Need to expand to undergraduate and high school
    ◦ Now possible! Easier to enthuse people through phenomena of study
  ◦ People from other disciplines to be encouraged to put ‘operations research’ as their area of work.
Implications: Computation $\rightarrow$ Empirical

Algorithms and Computational performance to become auxiliary

- Computations are important in OR, and provides an easy benchmark for performance.
- Mathematical theory and proofs are also important.
- However, they should not become the master.

OR is about empirical research and modeling
Towards Empirical Research in OR

Empirical research provides models that give rigorous and succinct explanation to a phenomenon
- Relies on/ derived from observations/ experiments
- The conclusions are verifiable by observation/ experiments
- Models usually written in formal language (e.g. Maths)
- Models should be explanatory

OR models are rigorous and give testable results (e.g. optimal solutions), but often are not explanatory
OR has good explanatory models.

Network flow models
- Critical path can be used to *understand* why projects run late.
  - (Unfortunately it does not give the schedule for the project.)

Linear Programming
- Explains why discontinuing some products may actually be beneficial (non-basic variables are 0): it’s counter-intuitive

Queuing Theory
- Why queues exist? Why queue length fluctuates over time?

Explanatory aspects need to be emphasized.
Towards Empirical Research in OR. (contd.)

OR models are typically prescriptive → might have led OR away from exploratory modeling, post optimality analysis and what-if scenario.

◦ Focus is more on recommendations to the client
◦ But client also needs to understand the problem to make ‘responsible decisions’.

Apart from providing understanding about a system/phenomenon, OR also prescribes appropriate solutions to the problems.
Implications: Publications and Teaching

Publications
- Focus on explanatory value rather than speed of algorithm
- Publish enlightening analysis even if there is no algorithm
- It is not going to be easy since most journals do not support it
  - Even empirical works are difficult to publish

Teaching and Capacity Building
- Hard OR: Necessary but not sufficient.
- Focus on explanatory nature of models
- Focus on Soft OR also: model building, empirical research, systems approach
- Range of content, from high school students level onwards
Implication: Practical relevance of OR

To help ensure practical relevance, OR must include methods to help structure the problem, as well as, the action plan for implementation.

Job of an Operations Research Practitioner is not complete until the problem is actually addressed!
Understanding Soft OR

Since 1970s, Soft OR developed by academicians/practitioners as a way to overcome difficulty in using Hard OR for practical problems. Soft O.R aims to build shared understanding in a group of decision makers ... for an agreed action plan that they are prepared to help implement.

Soft OR primarily refers to Problem Structuring Methods (PSM)
- Strategic Options Development and Analysis (SODA)
- Soft Systems Methodology (SSM)
- Strategic Choice Approach (SCA)
Understanding **Soft OR**

Over the years, other approaches are also used
- Theory of Constraints
- Causal Mapping
- Systems Thinking
- Benefits analysis
- Implementation Science
- And so..

**Teaching and Research on Soft OR is quite popular in UK**
- Not so popular in USA.
Beyond Empirical: Action Research in OR

Action Research is:

- Research *in* action, rather than research about action.
- Participative
- Concurrent with action, while building up body of knowledge
- A sequence of events and an approach to problem solving (iterative)
Conducting Action Research

Carrying out Action Research is not straightforward, and often time and resource intensive.

- We like linear activity: engage, analyze, act and disengage
- But AR is cyclic, until the problem is addressed completely.

Action Research may be based on a project in an industry

- But the project itself will proceed whether or not it is being studied!
- Problem Framing requires planning, implementation as well as insider knowledge of the organization

Skill set required is quite varied; Need to Learn in action
OR & ‘wicked problems’

Wicked problems are: “Problems difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize.”

◦ ‘Wicked’ denotes resistance to solutions
◦ Examples: Pandemics, climate change, energy access, healthcare, food security, economic growth and industrialization, etc.

Integrating Soft OR and Hard OR can help understand and make inroads into ‘wicked’ problems.
◦ OR as a catalyst for grand challenges
What the world is looking for...
Summary

Operations Research is the study of complex human activities and the formal structures therein
- OR to provide understanding and tools

OR community to keep the practical relevance of OR
- Emphasis on explanatory value: Post-optimality, sensitivity analysis and what-ifs
- Empirical modeling and research
- OR = {Hard OR, Soft OR, and Systems Thinking}
Bibliography


